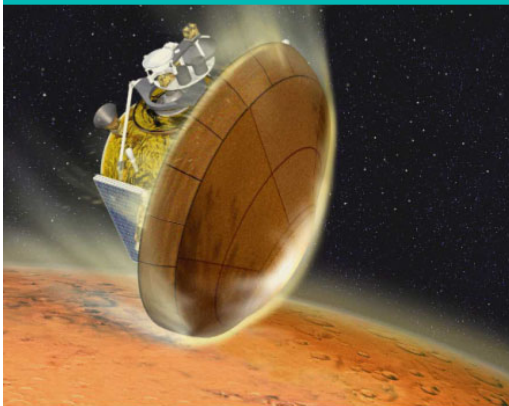


Thermal Management Electronically Biased Thermal Protection System

NASA Marshall Space Flight Center



Aerocapture uses a planet's atmosphere to create drag and slow the velocity of space vehicles without using propellant. This fuel-free braking system should reduce spacecraft mass, but tremendous heat is generated as drag is created by friction between the vehicle and the planet's atmosphere. The Space Shuttle leading edge reaches approximately 1650 °C (3000 °F) when the Shuttle enters Earth's atmosphere. Spacecraft can be designed with aeroshells by applying heat shielding to external surfaces. These aeroshells must weigh less than propellant-based orbital capture systems. The thermal protection systems (TPSs) for leading edges must be non-ablative, low mass, operated at high temperatures (1900 °C, 3452 °F), and insulated to protect internal vehicle parts. Studies have shown that radio frequencies can reduce the temperature by electrically biasing the surfaces of hypervelocity aircraft. In principle, a low-voltage DC bias to a spacecraft surface should inhibit energetic ions formed during reentry from transferring their energy to the TPS and thus reduce the heat load. Studies suggested

electrical biasing could reduce drag and reduce heating. This may increase the life of the TPS, which allows a reduction in TPS design mass.

Task Description

This Advanced Materials for Exploration (AME) study aims to demonstrate that electrical biasing can lower peak heating on TPSs by modifying ion-surface interactions and increasing plasma flow around the spacecraft's leading edge. Tasks include

1. Developing a prototype TPS test sample with an electrically biased coating
2. Testing the coated TPS in a hot gas environment
3. Evaluating the heat flux variance by comparing the electrically biased, coated sample to a sample with no electrical bias.

This 2-year effort was initiated in FY04 and will be completed in FY06.

Anticipated Results

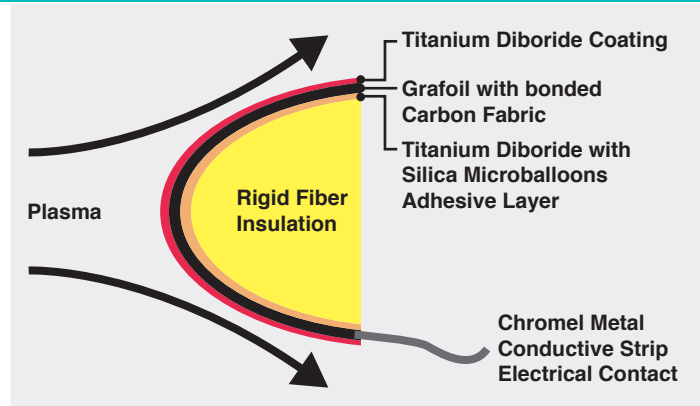
In FY05, investigators made test articles of different forms of carbon with various geometries and used a hydrogen-oxygen torch to produce temperatures and plasma gas. Embedded thermocouples provided temperature data. When the test article was heated, the electrical bias was created by applying a simple DC voltage of 5 to 12 V to the TPS coating. To obtain higher temperatures (1926 °C, 3500 °F), researchers tested different geometries and blowtorch styles. Temperature traces during a test using a flat graphite plate reached 1204 °C (2200 °F) and burned through Grafoil, a flexible paper-like form of graphite (carbon) that conducts electricity and is temperature resistant. These early tests revealed no effects generated by the electrical biasing on the TPS because the temperatures were too low and not enough plasma was generated.

advanced materials for exploration

ELECTRONICALLY BIASED THERMAL PROTECTION SYSTEM



Heat produced by a large surface mixing torch eventually burned through the TPS coating, but higher temperatures (1500 °C, 2732 °F) and more plasma were generated using another test article with this shape.



This diagram shows insulation with a titanium diboride coated Grafoil bonded to carbon fabric. When an electric current is applied, it may inhibit ion formation and thus reduce heating.

A smaller, thinner, round-shaped graphite test article provided the best results with temperatures reaching 1500 °C (2732 °F); heat was generated by a large surface mixing torch head. However, the test article showed little response to the applied voltage. Although the temperature was appropriately high and the torch generated plasma, the amount of plasma reaching the target was insufficient to demonstrate the effect. This is being improved by generating plasma more efficiently and reducing or eliminating the mixing of the atmosphere with the plasma stream. Investigators are repeating the test with a smaller target and a shorter distance between the torch and the target.

In FY06, a commercial plasma heating source and a vacuum plasma torch will be used to heat the test articles; these heat sources should produce higher temperatures and more plasmas, which will be a better test of the effectiveness of electrically biasing the TPS. Also in FY06, two ideal conductive outer coating materials were identified for future testing: titanium diboride (TiB_2) and boron carbide (B_4C).

Potential Future Activities

If the present study shows it is feasible to reduce temperature by reducing drag because the charged leading edge electrically rejects plasma, this process

could be scaled up. Investigators could build larger test articles with a variety of conductive coatings such as TiB_2 and B_4C , and perform a series of similar tests in Marshall Space Flight Center space simulators. If biasing does effectively cool the TPS, calculations should be made to determine the weight of the support electronics needed to enable biasing. Follow-on studies should compare the weight required to store and deliver power with the weight savings gained by not attaching heavy shielding or fuel-driven propulsion braking systems. This would provide rationale for building more elaborate electrically biased TPSs for future spacecraft.

Capability Readiness Level (CRL)

This AME task built small samples and tested them in a laboratory environment (CRL 3). Scaling up, refining these designs, and testing in a simulated space environment would elevate this technology to CRL 5. This technology supports fuel-free aerocapture, which could reduce the mass of interplanetary spacecraft, resulting in smaller, less expensive vehicles.

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